Tree-crop diversification in rubber plantations to diversify sources of income for small-scale rubber farmers in Southern Thailand

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Photo 1.
A hevea-salacca associated plot in Songkhla province. The farmer discovered that irrigating salacca in summer helped increase hevea latex yields by about 5-10%.
Photo V. Jongrungrot.

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RÉSUMÉ

DIVERSIFICATION DES CULTURES PÉRENNES DANS LES PLANTATIONS D'HÉVÉA POUR AUGMENTER LES REVENUS DES PETITS PRODUCTEURS DE CAOUTCHOUC DU SUD DE LA THAÏLANDE

Le caoutchouc est une culture de rente importante pour la plupart des petits agriculteurs. En Thaïlande, plus de 95 % du caoutchouc est produit par les petits agriculteurs qui cultivent principalement l'hévéa en monoculture (90 % des plantations). Mais du fait de la fluctuation des prix, la monoculture est de plus en plus souvent remplacée par des systèmes agroforestiers à base d'hévéa (SAF-hévéa). Cette étude a pour objectif d'évaluer les principales trajectoires des agriculteurs qui passent de la monoculture au SAF-hévéa. Les résultats montrent qu'ils suivent quatre trajectoires : conversion de leur verger de fruitiers en SAF-hévéa ; conversion de leur parcelle forestière en SAF-hévéa ; conversion de leur monoculture d'hévéa en SAF-hévéa ; création d'un SAF-hévéa dès la plantation. Il est également constaté que les planteurs pratiquent sept types d'association en fonction de l'utilisation économique des arbres intercalaires. L'étude économique a été complétée par une analyse SWOT (Strengths, Weaknesses, Opportunities and Threats) pour élaborer des lignes directrices qui permettront d'améliorer les plantations à base d'hévéa.

Mots-clés: caoutchouc, hévéa, agroforesterie, bien-être social, marge, productivité du travail, revenu agricole, Thaïlande.

ABSTRACT

TREE-CROP DIVERSIFICATION IN RUBBER PLANTATIONS TO DIVERSIFY SOURCES OF INCOME FOR SMALL-SCALE RUBBER FARMERS IN SOUTHERN THAILAND

Rubber is an important cash crop for most smallholders in Thailand, where more than 95% of rubber is produced by small farmers who mainly grow rubber trees (*hevea*) as a monocrop (90% of plantations). But monocrops are subject to price fluctuations, and this system is being increasingly replaced by rubber-based agroforestry systems (rubber-AFS). The aim of this study was to assess the main trajectories of farmers who have changed or are moving from monocrop to rubber-AFS. The results show four different patterns of diversification: growing fruit trees as a monocrop, then changing to rubber-AFS; growing timber trees as a monocrop, then changing to rubber-AFS; changing from monocrop rubber to rubber-AFS; starting with rubber-AFS from the beginning. We also found that farmers use seven types of crop associations in their plots, depending on the economic uses of the intercropped trees. A SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) was conducted in addition to the economic analysis, with a view to developing guidelines to improve the future of hevea-based plantations.

Keywords: rubber, hevea, agroforestry, social welfare, profit margin, labour productivity, farm income, Thailand.

RESUMEN

DIVERSIFICACIÓN DE LOS CULTIVOS PERENNES EN PLANTACIONES DE HEVEA BRASILIENSIS PARA AUMENTAR LOS INGRESOS DE LOS PEQUEÑOS PRODUCTORES DE CAUCHO DEL SUR DE TAILANDIA

El caucho es un importante cultivo comercial para la mayoría de pequeños agricultores. En Tailandia, más del 95 % del caucho es producido por pequeños agricultores que cultivan el árbol de caucho (hevea) principalmente en monocultivo (90 % de las plantaciones). Sin embargo, y debido a la fluctuación de los precios, se está sustituyendo cada vez más el monocultivo por sistemas agroforestales basados en caucho (SAF-caucho). El objetivo de este estudio es evaluar las principales trayectorias de los agricultores que pasan del monocultivo al SAF-caucho. Los resultados muestran que siguen cuatro trayectorias: conversión de plantación frutal en SAF-caucho; conversión de parcela forestal en SAF-caucho; conversión de monocultivo de caucho en SAF-caucho; creación de un SAF-caucho desde la siembra. Asimismo, se observó que los cultivadores practicaban siete tipos de asociaciones en función del uso económico de los árboles intercalados. El estudio económico se completó con un análisis SWOT (Strengths, Weaknesses, Opportunities and Threats) para la elaboración de pautas que permitan mejorar las plantaciones basadas en caucho.

Palabras clave: caucho, árbol del caucho, agroforestería, bienestar social, margen de beneficios, productividad del trabajo, renta de explotación, Tailandia.

Introduction

Smallholders produce more than 85% of the world's natural rubber (Somboonsuke and Wettayaprasit, 2013). In Thailand, the first world producer of natural rubber, 95% of the rubber is produced by smallholders, who, from the 1980s on, gradually decided to grow hevea, *Hevea brasiliensis* Muell. Arg., as a monocrop thanks to innovative technologies and subsidy programmes. Currently, about 90% of the rubber plantations in Thailand are monocropped hevea (Delarue and Chambon, 2012).

Although monocropped hevea can produce a satisfactory income when the price of rubber is high, negative impacts of monocropping are also possible: (1) loss of food security: in many parts of Thailand in particular, farmers have cut down trees in natural forests or replaced rice land to grow hevea, leading to a loss of biological diversity of local plants and animals (Rukyutitham, 2004); (2) production costs may be too high if the farmers have to rely heavily on external inputs (Thai Sustainable Agriculture Foundation, 2008); (3) years of agrichemicals use have resulted in soil acidification; (4) without a natural cover crop to protect the surface of the soil in the rubber plots, soil erosion during the rainy season has become common (Nissapa *et al.,* 1994); (5) global warming has reduced humidity in rubber plantations, resulting in lower rubber yields (Sdoodee and Limsakul, 2012); (6) farmer's income is subject to risk if it relies on a single commodity directly dependent on the international market with its frequent fluctuations (Nath *et al.,* 2013).

Tree-crop associations in rubber-based plantations can be a sustainable alternative to monocropping because the associated tree crops can generate substantial incomes (Snoeck *et al.*, 2013). Tree diversification was also found to be an important step forward by small farmers seeking to remain economically viable (Somboonsuke, 2001). It can also provide timber and environmental services (Joshi *et al.*, 2003). Tree diversification can help reduce the risk of the hevea being blown over during storms and reduce the amount and severity of surface runoff, resulting in less soil erosion (Kheowvongsri *et al.*, 2012). Plant diversification favours carbon fixation, and has also been shown to reduce daytime temperatures in summer in rubber-based intercropped plantations compared with monocropped hevea (Bumrungsri *et al.*, 2012).

Photo 2.
Hevea can also be associated with bamboo, a multi-purpose species.
Photo V. Jongrungrot.

During the field surveys of the study in the South of Thailand, it has been found that, although most rubber farmers still practice monocropping, some were spontaneously adding other tree species to their hevea plantations or hevea to their other monocrops, a strategy already observed during the 1990's in Indonesia and Thailand (Shueller *et al.*, 1997; Joshi *et al.*, 2003). The aim of this study was to explore the main trajectories of these farmers who have changed or are moving from monocrop to agroforestry systems. The main objective was to understand how farmers make the best use of empty spaces in their plantations. Intercropping tree-crops may be an opportunity to increase the sustainability of their rubber plantation, in particular for small-scale farmers who rely heavily on household labour. The other objectives were to: assess whether intercropping tree-crops in hevea plantation could be profitable in the near future; and develop guidelines to help small-scale rubber farmers in Southern Thailand improve their hevea plantations, even if the rubber price becomes more risky.

Materials and Methods

Study area

The study was conducted in Songkhla and Phatthalung provinces in Southern Thailand. Both provinces were selected because farmers practicing different types of hevea-based intercropping systems are found there. The climate is hot and humid with only two seasons: summer (February to July) and the rainy season (August to January).

Sampling and data collection

In 2012, twelve farmers have been selected who practiced hevea-based intercropping based on their social dimensions (membership of farmer in a group or a network of farmers-practicing and promoting hevea-based intercropping) and the diversity of intercropped plants in their hevea plots. The 12 farms had a total of 19 hevea-based intercropped plots used for observation of bio-physical components to assess the development of some ecological perspectives of hevea-based intercropping plots, and of the farming systems for socio-economic characteristics of the farms concerned.

Eight plots have been selected out of the 19 plots based on the: (1) economic outputs (margin per ha) in 2012; (2) potential to generate a higher income by intercropping; (3) hevea age categorized in four groups (‹ 7 years old, 7-15 years old, 16-25 years old, › 25 years old); (4) and species diversity to conduct a prospective analysis for the decade 2012-2021.

Data analysis

The following analyses were carried out:
- A descriptive statistic to estimate the proportion of hevea-based intercropping plots in the total landholding. The diversity of intercropped plants was categorized based on their economic use in timber species, fruit trees, and other plants, including flowers and ornamentals.

Table I.
Amount of raw rubber sheets as a function of the age of the heveas.

Age group of heveas (years)	Amount of raw rubber sheets (kg/ha/year)	(%)
7- 9	1,531	64
10-12	2,375	100
13-15	1,900	80
16-18	1,575	66
Over 19	1,350	57

Source: calculation based on Gunalasiri *et al.*, 2007.

▪ A processual analysis was used to study the past development of hevea-based intercropping systems and to link the processes to the location, the timeline of monocropping and intercropping and the outcomes of the hevea-based intercropping plots.
▪ Olympe© software was used for technical and economic modelling of the farms, and to compare the different farm types based on their economic aspects and on the total annual income of the households. “Olympe” is a simulation tool which allows a prospective technical-economic analysis over a ten-year period based on the current farm data. It can build scenarios and characterise farmers’ strategies to identify possible development axes to help farmers take the appropriate decisions (Penot, 2004).
▪ A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was used to evaluate the social and labour dimensions of the farm households in our sample.

Based on these results, guidelines were designed to improve recommendations in hevea plantations of the small-scale rubber farmers in Southern Thailand in the coming decade. Economic data were mostly collected during interviews with the farmers. They included the actual amount of farm inputs and of intercropped and other plant productions in 2012 and estimated for the decade 2012-2021. All prices were based on the real prices given by the farmers in 2012 (except rubber). The amounts of rubber latex in 2012 were obtained from the farmers. For the decade 2012-2021, they were estimated from the study by Gunalasiri *et al*. (2007) for the different hevea age groups (table I). The actual prices of latex in 2012 were obtained from the central rubber market in Hat Yai because the price is fluctuating and most farmers did not keep records and the price was fixed for the period 2012-2021.

Results

Size of farm and distribution of intercropped area

The farmers in the sample held an average of 3.18 ha of farmland, from 1.12 ha to 7.44 ha (figure 1). All farms taken together, the average size of hevea-based intercropped plot was 2.1 ha, from 0.64 ha to 6.72 ha.

The ratio of hevea-based intercropped area to total farm area was used to classify the farms in three groups:
▪ Three farms had 100% hevea-based intercropped plots, two of which were the smallest areas.
▪ Five farms had between 50% and 100% hevea-based intercropped plots. Most grew timber and other tree species in the rubber plots.
▪ Four farms had less than 50% hevea-based intercropped plots. Each of these had only one hevea-based intercropped plot, while the remaining plots were monocrops of hevea, or fruit tree, or vegetable, or rice fields.

Plant diversity in hevea-based intercropped plots

Hevea was associated with different kinds of timber or fruit trees or other economic plants, or any combination of these (table II). In all, there were 21 kinds of timber, 10 kinds of fruit trees, and 9 kinds of other plants. The most popular intercrop species was Ironwood, found in seven plots, followed by Gnetum and bamboo, each found in five plots. Next came Eagle wood, White Meranti, and Salacca, each found in four plots.

Regarding plant diversity, between 2 to 12 species were observed per plot, with a density of 368 to 5,125 trees per ha. The plots with the highest plant diversity also had the highest tree density. In most of these plots, timber species were the main intercropped species because they required less maintenance and thus had lower operating costs. In these plots, the owners aimed to conserve biodiversity and favour environmental services, whereas in plots with lower plant diversity, tree density was also lower, and most of their owners wished to increase their income by intercropping.

Development of hevea-based intercropped plots

The development of the hevea-based intercropped plots depended on the farmers’ strategies to optimize land use. This was mostly achieved by filling empty spaces with new species with the aim of reducing economic and environmental risks. The intercropped species were chosen by the farmers based on their experiences and observations, the advice of neighbours, and the availability of varieties distributed by public institutions, a key factor in farmer’s decision. The planting densities were determined by the farmer’s own experience, the advice of neighbours, and the limited availability of farm labour.

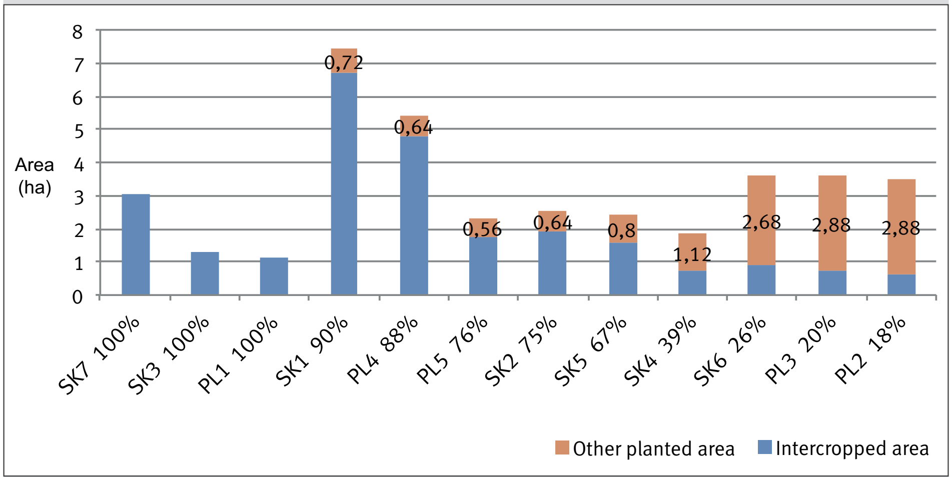

Figure 1.
Size of rubber-based intercropped area and other cultivated areas to total farm area.

The development of the plots followed four trajectories:

▪ First growing fruit trees, then gradually turning to hevea-based intercropping

Three plots developed in this way (plots 6, 8 and 14). Most fruit trees were over 30 years old when hevea was planted. Farmers introduced heveas when the price of rubber was high. In 2012 (the year of the survey), none had been tapped yet. In plot 14, the farmer had added timber, bamboo and Gnetum before planting heveas.

▪ First growing timber trees, then gradually turning to hevea-based intercropping

Two plots developed in this way (plots 2 and 3). In both plots, the planting density of trees was very high (about 2-3 times more than usual) because the owner was trying to force the timber trees to grow straight upwards.

▪ First growing hevea, then converting to hevea-based intercropping after tapping started

Nine plots developed in this way (plots 1, 7, 9, 10, 11, 15, 17, 18 and 19). Most farmers grew heveas only with support from the Office of the Rubber Replanting Aid Fund (ORRAF). These plantations were established before 1992. At that time, ORRAF required that farmers grow no other species in their hevea plantations, except short term crops in the first years. Later, when the price of rubber was low, the farmers gradually converted these plots to intercropping.

▪ Growing hevea-based intercrops from the beginning or during the first four years

Five plots developed in this way (plots 4, 5, 12, 13 and 16). Most farmers grew hevea with support from the ORRAF which after 1993, allowed farmers to grow intercrops. One plot began intercropping when the price of rubber was low, whereas the other four began when the price of rubber was high.

Economic benefits of hevea-based intercropped plots

Comparison of margins in hevea-based intercropped plots in 2012

Table III lists the 19 hevea-based intercropped plots. Two plots produced rubber only, eleven plots produced both hevea and intercropped trees, five plots produced only intercropped trees, and one plot had not yet produced anything. Operating costs concerned organic and chemical fertilisers, fuel, seedlings, small equipment, ethylene (used for latex flowing stimulation to increase yield), and external daily labour to cut grass, apply fertilizer, tap the heveas and harvest products when the farmers were too old, or lacked household labour, or were sick or busy with other full-time jobs.

In 2012, the margins (selling price – operating cost) ranged from – US$22 to + US$17.42 per ha with an average of US$5.11 per ha.

Both socio-economic and bio-physical factors were responsible for the difference in the margins. These factors were classified as positive or negative and divided into three categories:

1- Factors affecting the latex yield:

Positive factors

▪ Soil naturally containing organic matter and humidity (plots 1, 4, 5, 7, 9, 10, 11, 13, 15, 16, 17, 18, 19).
▪ Shaded plantations with sufficient humidity and different tree canopies (same plots).
▪ Associated trees are below the heveas (same plots).
▪ Farmers applied chemical fertiliser and ethylene to old heveas (plots 9, 15, 17).
▪ Heveas were at the age of highest yield (plots 5, 13, 14).

Negative factors

▪ Competition between heveas and associated trees for soil nutrition (plots 1, 7, 10, 18).
▪ Heveas were immature or past the peak yielding age (all plots excepting plots 5 and 13).

2- Factors affecting the amount and value of intercropped plant production:

Positive factors

▪ Effect of hevea shade on fruit quality of associated crops; e.g. glossier mangosteen peel or less bitter Gnetum leaf (plots 7, 10, 15, 16, 17, 18, 19).
▪ Harvesting period harvested could be extended; e.g. Salacca, Gnetum, bamboo, and Yellow palm leaves (plots 7, 9, 10, 11, 13, 14, 15, 17, 18, 19).
▪ Income diversification (plots 6, 13, 14).
▪ Farmers applied organic and/or chemical fertiliser to intercropped plants thus increasing yields (plots 1, 2, 7, 8, 9, 12, 13, 14, 15, 16, 17).

Table II.
Plant diversity expressed as the number of heveas, *Hevea brasiliensis* L., and intercropped species per ha.

Plot No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Area (ha)	2.40	4.00	0.32	0.80	0.16	0.96	0.96	0.32	0.72	1.60	0.92	0.80	2.24	1.12	0.64	0.72	4.80	0.64	1.12
Rubber, *Hevea brasiliensis* L.	438	1,500	1,250	538	375	104	625	531	419	500	438	500	444	181	438	463	456	438	538
Timber species																			
1. Ironwood, *Hopea odorata* Roxb.	219	2,000	1,250	13								375	181	206					
2. Eagle wood, *Aquilaria crassna* Pierre	438	1250		25									23						
3. Malacca teak, *Intsia palembanica* Miq.													4						
4. Mahogany, *Swietenia macrophylla* King.												125		138					
5. Yang, *Dipterocarpus alatus* Roxb.												375	181						
6. White Meranti, *Shorea roxburghii* G. Don.				19								125	44	150					
7. Champaka, *Michelia champaca* Linn.				9															
8. Mouimein Cear, *Toona ciliata* M. Roem.														88					
9. Bur-flower, *Anthocepalus chinensis* (Lamk.												50							
10. Neem, *Azadirachta excelsa* (Jack) Jacobs.												63	44	119					
11. Gendarussa, *Justicia gendarussa* Burm. f.																		469	
12. Bastard garcinia, *Garcinia merguensis* Wight																		625	269
13. Black Mangrove, *Lumnitzera littorea* (Jack) Voigt																		81	88
14. Sea apple, *Eugenia grandis* Wight																		156	
15. Ilex, *Ilex cymosa* Blume																		313	
16. Cenderai, *Microcos tomentosa* Smith.																		50	
17. Needle Wood, *Schima wallichii* (DC.) Korth.																		81	
18. Suk-hin, *Cordia globifera* W.W. Smith																		31	
19. Hard alstonia, *Alstonia macrophylla*																		81	
20. Tung, *Litsea grandis* L.																			88
21. Jambolan Plum, *Syzygium cumini* (L.) Skeels																			88
Fruit trees																			
1. Longkong, *Lansium domesticum* Corr.	81	25												131					
2. Lansium, *Lansium domesticum* Serr.						13													
3. Mangosteen, *Garcinia mangostana* L.	81									63						206			
4. Champeak, *Artocarpus integer* Merr.	6					138													
5. Durian, *Durio zibethinus* Linn.	169					63								38					
6. Rambutan, *Nephelium lappaceum* Linn.														31					
7. Coconut, *Cocos nucifera* Linn.								75						13					
8. Jerin *Archidendron jiringa* I. C. Nielsen	81																		
9. Stink bean, *Parkia speciosa* Hassk.						50		19											
10. Salacca, *Salacca edulis* Reinw.				550	375							1,125	1,025						

Table II (end).

Plot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Area (ha)	2.40	4.00	0.32	0.80	0.16	0.96	0.96	0.32	0.72	1.60	0.92	0.80	2.24	1.12	0.64	0.72	4.80	0.64	1.12
Rubber, *Hevea brasiliensis* L.	438	1,500	1,250	538	375	104	625	531	419	500	438	500	444	181	438	463	456	438	538
Other plants																			
1. Gnetum, *Gnetum gnemon* Linn.				500			206							38	469				356
2. Bamboo, *Bambusoideae*									419	281		250	56	44					
3. Livistona, *Livistona speciosa* Kurz.											106								
4. Fan Palm, *Licuala paludosa* Griff.										125								238	88
5. Yellow palm, *Chrysalidocarpus lutescens* H. Wendl.																	4,669		
6. Sealing wax palm, *Cyrtostachys renda* Blume																			131
7. Litter Collecting Palm, *Johannesteijsmannia altifrons* (Rchb. & Zoll.) H. E. Moore																			131
8. Flowers and ornamental plant		106																	
9. Pandanus palm, *Pandanus amaryllifolius* Roxb.									206									19	
Total	1513	4,881	2,500	1,654	750	368	831	625	1,044	969	544	2,988	2,002	1,177	907	669	5,125	2,582	1,777
Number of species per plot	8	5	2	7	2	5	2	3	3	4	2	9	9	12	2	2	2	12	9

Negative factors

▪ Timber grown for environmental rather than economic reasons, thus not sold (plots 1, 2, 4, 12, 13, 14, 18, 19).
▪ Labour and time competition between associated crops (plots 4, 6, 11).
▪ Lower yields of light-demanding species, like Mangosteen (plot 1).

3- Factors affecting operating costs:

Positive factors

▪ Better management, less fertiliser use and reduction of unnecessary farm-works (plots 1, 2, 10, 12, 13, 18, 19).

Negative factors

▪ Distance between the plots and the farmer's home or market (plot 6)
▪ Hired labour due to farmer's age or bad health, or external activities (plots 7, 8, 14, 15, 17).

Comparison of simulated margins of hevea-based intercropped plots in the 2012-2021 decade

Based on the simulation of margins of the eight plots for the decade 2012-2021, the plots could be divided into 3 groups. The trajectory of the eight most representatives is described below and in figure 2.
▪ High margins with a gradual increase and step increase: plot 9 (trajectory 4) and plot 13 (trajectory 3).
▪ Medium margins with a gradual increase and fluctuating development: plot 19 (trajectory 4), plot 7 (trajectory 4), plot 16 (trajectory 3), and plot 4 (trajectory 3).
▪ Low margins with a gradual increase: plot 1 (trajectory 4) and plot 14 (trajectory 1).

Overall comparison of the estimated margins showed that: all plots will have a higher margin per ha in 2021 than they had in 2012; and six out of the eight plots will have a higher margin per ha during the period 2013-2021 than they had in 2012. These two findings have the following main causes: heveas or intercropped plants will continue to yield with age; after 2013, the heveas in four out of the eight plots will be more than 21 years old and their yield will remain unchanged, but the yields of the intercropped trees will increase with age or will start to yield; and the old heveas in one out of the eight plots will be cut down by the farmer and sold as timber.

Photo 3.
Hevea other crops association (here Gentum) allows sharing financial risk between various outputs.
Photo V. Jongrungrot.

Table III.
Margin of rubber-based intercropping plots in 2012 (in US$/ha).

Plot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Area (ha)	2.4	4	0.32	0.8	0.16	0.96	0.96	0.32	0.72	1.6	0.92	0.8	2.24	1.12	0.64	0.72	4.8	0.64	1.12
Value																			
Rubber	3,511			768	11,556		555		14,597	6,175	5,078		7,924		10,033	8,471	3,325	2,809	10,805
Timber																		54	
Fruit tree	9					3,396		623				2,730	697	3,777		580			
Other plants		31					3,969		3,303	173	75		418	140	5,417		4,681	325	434
Total	3,520	31		768	11,556	3396	4,524	623	17,900	6,348	5,153	2,730	9,039	3,917	15,450	9,051	8,006	3,188	11,239
Operational cost																			
Seedling												607	131	22					
Organic fertiliser	401	47		57	520		58					8	58	466			673		232
Chemical fertiliser							497	309	398	87	199		21	305	390	513	464		
Fuel		6		6	164	586	77	113	14	37	133	26	63	6	147	171	89	82	126
Small equipment						109									70		3		
Ethylene									68						36		13		
Labour							375	216						449	1,084		1,209		
Total	401	53		63	684	695	1,007	638	480	124	332	641	273	1,248	1,727	684	2,451	82	358
Margin	3,119	-22		705	10,872	2,701	3,517	-15	17,420	6,224	4,821	2,089	8,766	2,669	13,723	8,367	5,555	3,106	10,881

Socio-economic characteristics of farm households practicing hevea-based intercropping

Income of farm households practicing hevea-based intercropping

Table IV lists the total income of the 12 farm households and the share of income from the intercropped plots in comparison with the income from other plots (monocrop hevea, fruit trees, rice, vegetables, etc.) and with off-farm incomes. Examples of off-farm incomes are welfare aid for the elderly, salary for government officials, private employees, and assistant village heads, honorarium for village health volunteers and trainers, income from owning a computer store.

Based on the total annual incomes calculated in 2012, the farm households were divided into three groups (Table IV):

- High total annual income (over US$34.67): Farms with large areas, good cultural practices (e.g. use of ethylene to increase rubber yields), high income from intercropped plants which can be harvested all year round, off-farm income or private business.
- Medium-high total annual income (17,34 to US$34.67): Farms with large areas, but lower cultural practices, less associated crops were yielding; or competition with off-farm activities.
- Medium total annual income (below US$17.34): Farms with average areas, had a small farm, poor cultural practices, associated crops not suited to their environmental conditions, low off-farm income.

Analysis of the social and labour dimensions of the farm households

Table V lists the number of household members and labour, farm size and land use, and ratio of farm size to available farm labour. The ratio among the 12 farmers ranged from 0.46 to 7.44 ha per person.

Based on table V and related data a SWOT analysis has been performed to assess social and labour dimensions:

- Strengths - Seven farmers owned intercropped plots which could be a base for the promotion of this practice in their communities; nine farmers had set up a group in their communities and/or a network with other communities and other sectors to share knowledge and promote intercropping; 10 farmers allocated some of their time and labour to working off the farm to increase their income and improve family welfare.
- Weaknesses - Six farmers were over 60 years old (two of them were over 70 years old). There was no household labour available to work in the farms and no one or only female members to continue farming in the future.
- Opportunities - At the time of the study (2012), the Office of the Rubber Replanting Aid Fund allowed members to grow other tree species in their plots.
- Threats - The 300-Baht minimum wage policy which came into effect in January 2013 increased the cost of hiring labourers on farms without sufficient household labour. The impact will be even greater when the sales prices for farm products are low, as the farmers will have even fewer resources to hire additional labour.

Discussion

The results show that farmers started hevea-based intercropping for several reasons. When the price of rubber was high, farmers decided to add heveas to their timber or old fruit trees. When the price of rubber was low, farmers changed from monocropping to intercropping. Some farmers practiced intercropping for environmental reasons.

The choice of species depended on several factors: farmer's awareness of the recovery of biodiversity to create a balanced ecosystem and help reduce the effect of global warming through agroforestry; farmer's experience and knowledge of the plants that grow well with hevea; environmental conditions including the type of soil; most plantations had sandy loam soils which do not hold water well, so farmers needed to grow other species that increase soil humidity; marketing channels and the value of intercropped plants; and government promotion and the provision of free seedlings.

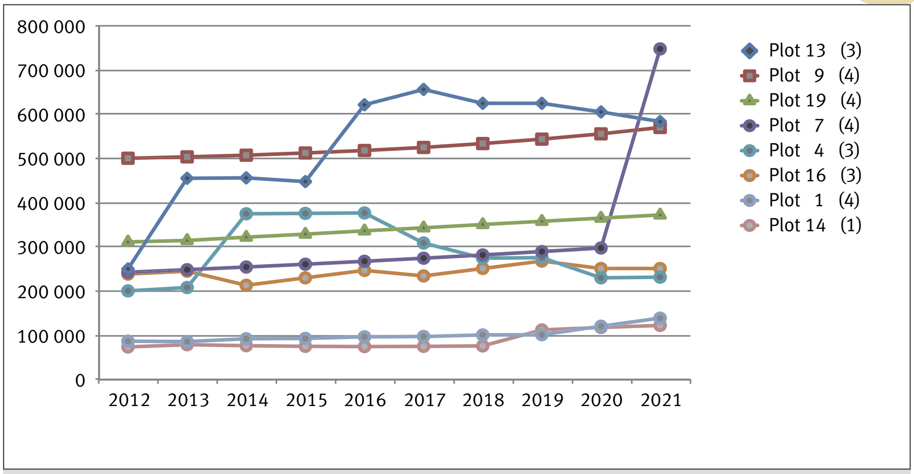

Figure 2.
Margin of rubber-based intercropping plots during the 2012-2021 decade ranked by plot n° and trajectories (in parenthesis).

This study showed that farmers were aware that they could increase their income by increasing the diversity and the number of associated crops. This is in agreement with observations by Kheowvongsri (2008) who reported that hevea-based agroforestry provided farmers with income from hevea tapping, selling timber after cutting down old heveas, and selling products from intercropped plants at different periods of time. When tapping is not possible, income from other intercropped plants could be a good compensation. Simien and Penot (2011) indicated that the bigger the share of income from the other crop, the better it will help the farmer survive a decline in the price of rubber. Besides, as reported by Shueller *et al.* (1997), the hevea can withstand up to 250 tree ha^{-1} of associated trees provided that their canopy does not exceed that of hevea.

Table IV.
Total annual income (US$) of the farm households in our sample in 2012.

Farm households	Total annual income	Income from intercropped plots (%)	Income from other plots (%)	Off-farm income (%)	Farming area (ha)	Use of ethylene	Yielding area
High	› 34,674						
1. PL 4	72,059	37.0	4.6	58.4	5.44	yes	highest
2. PL 2	36,475	24.1	74.1	1.8	3.52	yes	high
3. SK 4	35,272	35.5	29.1	35.4	1.84	yes	highest
4. SK 7	35,039	60.8	0.0	39.2	3.04		medium
Medium-High	34,674 – 17,337						
5. SK 1	23,350	31.7	0.0	68.3	7.44		fairly low
6. SK 6	21,270	20.8	50.6	28.6	3.60		high
7. PL 1	20,563	14.5	0.0	85.5	1.12		medium
8. PL 5	17,623	80.4	17.4	2.2	2.32		medium
Medium	‹17,337 – 8,669						
9. SK 2	14,831	67.3	14.2	18.5	2.56		medium
10. PL 3	13,178	45.7	50.4	3.9	3.60		low
11. SK 3	13,158	62.1	0.0	37.9	1.28		medium
12. SK 5	12,922	77.1	3.9	19.0	2.40		medium

Table V.
Number of household members and labour, farm size, and ratio of farm size to labour.

Items	Case studies											
	SK 1	SK 2	SK 3	SK 4	SK 5	SK 6	SK 7	PL 1	PL 2	PL 3	PL 4	PL 5
Household members (total)	5	6	3	4	5	4	6	4	4	4	4	3
Available family labour	1	3	1	4	3	3	3	1	4	2	2	3
Off-farm labour	1	1	1	1	2	1	2	1	1	0	3	0
Farmer's age	71	49	65	64	46	64	55	80	60	49	56	65
Hired labour	2	0	1	0	0	2	0	0	0	1	2	0
Preparation for farming	0.72	0	0	0	0	0.16	0	0	0	0	0	0
Rubber + intercropped plants	6.72	1.92	1.28	0.72	1.6	0.92	3.04	1.12	0.64	0.72	4.8	1.76
Home garden	0	0	0	0	0	2.08	0	0	0.32	0	0	0
Monocrop rubber	0	0	0	1.12	0.64	0.44	0	0	2.24	2.88	0	0
Rice + vegetables + flowers	0	0.64	0	0	0	0	0	0	0	0	0.64	0.56
Fruit tree + perennial crop	0	0	0	0	0.16		0	0	0.32	0	0	0
Farming area (ha)	7.44	2.56	1.28	1.84	2.4	3.6	3.04	1.12	3.52	3.6	5.44	2.32
Ratio of farm size to available farm labour (ha/person)	7.44	0.85	1.28	0.46	0.80	1.20	1.01	1.12	0.80	1.81	2.72	0.77

The survey showed that some farmers were aware of the value of intercropping regardless of fluctuating rubber prices. They practiced intercropping for its economic benefits and for the environmental services it provides. This is consistent with the results of several studies by scholars in Thailand and overseas. For example, Joshi *et al.* (2003) found that hevea-based agroforestry systems could generate income from various species, increase food security and timber, provide environmental benefits, including biological diversity, carbon dioxide fixation, watershed protection and soil conservation. Lin (2011) reported that agroforestry systems also protect crops from extreme storm events (e.g. hurricanes, tropical storms) in which high rainfall intensity and hurricane winds can cause landslides, flooding, and premature fruit drop from crop plants. Bumrungsri *et al.* (2012) reported that hevea-based intercropping plantations had more fallen leaves, organic matter, and higher decomposition rate of leaves than monocrop hevea plantations. Although hevea-based intercropping does not provide the plots with water directly, there was more humidity in these plots in the dry season than in monocrop hevea plots, which is beneficial for higher latex yields (Sdoodee *et al.*, 2012).

However, despite the benefits demonstrated in our study, which supports previous ones cited above, hevea-based intercropping currently remains not popular in Thailand. This is partly because the farmers lack the knowledge and skills required for this system; they do not have enough time and labour to take on the additional workload; the price of rubber has continued to rise since 2002; and finally, research and the dissemination of research results on hevea-based intercropping is still limited. To assess the optimal labour to perform the necessary tasks on the farm, it has been taken into account the number of persons living in the farm household who were available for farming activities. However, the ratio alone was not enough to assess whether the farmer should adopt this system, it had to take other factors into consideration; for example, age, sex, health, types of intercropping systems, management capacity and access to hired labour. Results showed that most farmers in our sample tried to adjust their practices to create a balance between the size of the farm and household labour in different ways. For example, SK1 who had the highest ratio of 7.44 ha per person, was the only labourer on his own farm. At the time of the study, he was a healthy 71-year old man. Along with hevea, he grew a lot of timber species like Ironwood and Eagle Wood, which needed very little care. He hired labour to tap and collect latex. At the time of the study, he had stopped working in the plantation himself and instead grew flowers and ornamental plants in a small area. In this way, he was able to work less as befit his age. SK3 had a ratio of 1.28 ha per person. She was a healthy 65-year old woman and the only farm labourer in her family. Along with hevea, she grew Gnetum which required trimming once a year, and 116 days per year to collect its leaves for sale. She spent about 95 days a year tapping and hired labour to help apply fertilizer, mow weeds and harvest fruits. In the future, because she is a women and because of her age, she will need to hire more labour.

Guidelines to improve the rubber plantation of small-scale rubber farmers in Southern Thailand in the coming decade

Today, the price of rubber is going down and growing hevea may be more risky in the next decade for several reasons: economic growth in China, the first world importer of natural rubber (RRIT, 2013), is slowing down and Chinese development will consequently be more balanced (economic, social, and environmental dimensions); Europe and the USA have not recovered from the current economic crisis; and the size of rubber plantations in many other countries has expanded considerably in the past decade. So, any guidelines to improve the rubber plantation of small-scale farmers in Southern Thailand in the next decade should include the following recommendations:

Photo 4.
A hevea-livistona plot in Songkhla province provides income from both latex and livistona leaves sale, and the rest for self-use such as making roof, bag, mat.
Photo V. Jongrungrot.

Introduce intercropping in rubber monocrop plantations. This can help to reduce and spread the risk of fluctuating prices of farm commodities, increase food security, and provide environmental services. Based on the findings of this study, some intercropping trees that ought to be planted are: useful and profitable timber species, both hard wood and softwood, including Ironwood, Eagle Wood, Champaka, Neem, White Meranti; fruit trees to spread price risk and ensure some food security; and other profitable plants such as Gnetum, bamboo, Salacca, and Yellow palm.

Increase income from intercropped plants. Benefits from intercropped trees can help increase the total farm income through: more efficient plot management (lower maintenance and operating costs); increased yields of intercropped fruit trees (for example, more pollination of Salacca); introducing other kinds of products in the plots to increase household income (for example changing from harvesting to grafting and selling more Gnetum); adding a source of income to compensate for lower price of rubber or higher farm labourers' wages (Jongrungrot and Thungwa, 2014).

Choose optimal spacing and the best planting dates. Farmers interviewed said that standard hevea planting densities in rows (3 m in a rows separated by 7 m) is sufficient to allow intercropping. Our results showed that farmers should plant hevea first and only plant intercropped trees when the heveas are mature. For example, bamboo should be planted when the heveas are 4-5 years old so they do not compete for food. Eagle Wood should be planted when the heveas are 7 years old as the roots of the heveas can intertwine with those of the Eagle Wood and help prevent them being blown over during storms. Mangosteen should be planted when the heveas are 1-2 years old because a growing Mangosteen needs a lot of sunlight.

Know whether the necessary farm labour is available. Availability of agricultural labour is important because intercropping requires more care and time than hevea monocropping. Particularly when a farmer wishes to start or increase intercropping. Also, the farmer should estimate whether the income from intercropping will cover all operating costs including hired labour.

Be organized. Farmers who practice hevea-based intercropping are advised to create groups in their communities and/or networks among stakeholders so they can help each other by sharing technical knowledge, marketing together, supplying collective labour, sharing varieties, and so on. In addition, the farmers should choose the right intercrops for their location and type of soil.

Conclusion

The 12 rubber farmers in the sample in Songkhla and Phatthalung in Southern Thailand had 19 hevea-based intercropping plots. The intercrop species composed of 21 kinds of timber, 10 kinds of fruit trees and 9 kinds of other plants. Ironwood, Gnetum, bamboo, and Salacca were popular intercropped plants because they grow well with heveas and meet market demand. Each plot contained between 2 and 12 kinds of intercropped plants, between 368 and 5,125 trees per ha. Four development trajectories of hevea-based intercropping system were identified: growing different kinds of fruit trees first, then gradually changing to hevea-based intercropping; starting hevea-based intercropping after tapping monocrop hevea; starting hevea-based intercropping before beginning to tap monocrop hevea; and growing heveas in timber plots. These four trajectories represent a wide range of hevea-based intercropping systems with different numbers of intercrop species and densities.

Overall, the farmers gained several economic and environmental advantages from hevea-based intercropping: (1) the soil contained more organic matter and soil humidity was higher; (2) hevea plantations were subject to less soil erosion and had fewer weeds; (3) some parts of the plot were shady so the hevea bark was soft and produced more latex; (4) the quality of hevea-based intercropping products was higher; (5) and the increased biological diversity of these plots created a balanced ecosystem and helped prevent damage caused by storms. However, based on the margins of 19 plots in 2012, the economic benefits varied due to several positive and negative factors that affect the yields of hevea and intercropped plants as well as operating costs. The ten-year margins (2012-2021) of eight intercropped plots were divided into three groups: high, medium, and low. Factors affecting their future development include the use of ethylene, the yield of hevea and intercropped plants depending on their age, the value of each intercropped plant, the level of care required in each plot, and finally whether intercropping was practiced for the purpose of conservation. The farm households' total annual income in 2012 could be divided into three groups: high, medium-high, and medium. Factors affecting total annual income included the size of the farm, access to market, and the ratio of farm to off-farm income. In addition, the study revealed weaknesses, strengths, opportunities, and threats to the social and labour dimensions of the farm households, and identified the farmers' adaptive efforts to find a balance between farm size and household labour. The results of the study are consistent with those of several scholars in Thailand and overseas on the economic and environmental benefits of hevea-based intercropping and provide new information for the community in the form of guidelines to help improve hevea plantations of small-scale rubber farmers in Southern Thailand in the coming decade.

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